refrigerants that are not greenhouse gases, as called for in the 2016 Kigali Amendment to the Montreal Protocol. Technology to capture and recycle waste heat would make air conditioning even more efficient and would reduce its contribution to the urban heat island effect.

**Future form of the indicator**

The indicator in the 2021 report estimated the number of heat-related deaths averted by air conditioning in the 65-and-older population by country/region and for the world. There were a number of limitations to these estimates, such that they were considered to be "ballpark" estimates that would need considerable refinement in future years. The intention is to present improved estimates in future years, including all age groups. In addition, city-level case studies to estimate number of lives saved from air conditioning versus premature deaths from exposure to $PM_{2.5}$ due to air conditioning may be performed. The indicator may be updated each year as new data become available on air conditioning use. Trends in vulnerability to heatwave-related mortality could be assessed with cooling degree days. Finally, metrics related to more efficient cooling (e.g., national building codes, minimum energy performance standards, labelling rules for air conditioners) and progress on implementing the Kigali Amendment may be tracked in the future.

## *Indicator 2.2.3: Urban Green Space*

**Indicator authors**

Prof Patrick Kinney, Dr Jennifer D. Stowell

**Methods**

Urban centre spatial extents were defined by the Global Human Settlement (GHS) program of the European commission.[165] The GHS uses remote sensing and demographic data to define more than 10,000 urban centres worldwide. Urban centres chosen for the indicator were identified as urban centres larger than 500,000 inhabitants. To include countries with no urban centres that met this threshold, we selected the most populated city where possible, giving a final count of 1,041 urban centres and 174 countries. Due to missing data in either the GHS or the Normalized Difference Vegetation Index (NDVI) data, 22 countries (mostly small island states) were not represented in the analysis.

Data on population size for all years were collected from the Center for International Earth Science Information Network (CIESN, Columbia University), which models the distribution of human population at 30 arc-second output resolution.[166]

Green space was estimated using the normalized difference vegetation index (NDVI), the most commonly used satellite-based vegetation index. NDVI calculates the ratio of the differences between near infrared radiation and visible radiation to the sum of these two measures. NDVI values range from -1·0 to 1·0 with values less than 0 indicating water and values close to 1 indicating high levels of vegetation density.[167] For this process, we used publicly available data from the Landsat satellite, a joint program of the USGS and NASA.[168] Landsat images the Earth's surface at 30-meter resolution approximately every two weeks (~16 days). To account for seasonal fluctuations, we computed NDVI for each of the following time periods (with season labels based on the northern hemisphere):

- Winter—December 1 of previous year through February 28
- Spring—March 1 through May 31
- Summer—June 1 through August 31
- Fall—September 1 through November 30

We did this for four different years: 2015, 2020, 2021, and 2022. In previous iterations of this indicator, 2010 was also included. However, due to a known equipment malfunction in Landsat7, we have elected to remove 2010 from this update. Landsat 8 (2015, 2020, 2021) and Landsat 9 (2022) were used to estimate values for the included years. For each year and city, a total of four exposure metrics were calculated: peak NDVI (maximum NDVI across the four seasons); annual mean NDVI based on the four-season average NDVI; population-weighted average peak NDVI; and population-weighted mean NDVI. The population weighted NDVI was computed for each city by multiplying each NDVI value (peak and four-season average) by the population size of the corresponding year within the same 1x1 km raster, summing up over the weighted values within the urban extent, and dividing by the sum of the weights, as shown by the equation below:

$$\frac{\sum_{i=1}^{n}(NDVI_i * population_i)}{\sum_{i=1}^{n}(population_i)}$$

Additional analyses include subsetting the data by levels of the Human Development Index (HDI, see Figure 1), climate regions as defined by the Köppen Climate Classification System (see Figure 2), *Lancet* Countdown regional country groupings, and WHO region.[169] Google Earth Engine was used to generate raw data and the R Statistical Software was used for data analysis and management and to compute the four metrics described above. ‘Level of Greenness’ was defined according to the table below:

**Table 33 Categorization of Greenness Levels**

| Level of Greenness | Population-Weighted Peak NDVI |
|---|---|
| **Exceptionally Low** | <0·20 |
| **Very low** | 0·20-0·29 |
| **Low** | 0·30-0·39 |
| **Moderate** | 0·40-0·49 |
| **High** | 0·50-0·59 |
| **Very High** | 0·60-0·69 |
| **Exceptionally High** | ≥0·70 |

**Data**

1. Global Human Settlement Programme of the European Commission (GHS) used to identify urban centres.[165]
2. Population size identified from NASA GPWv4.[170]
3. Satellite data were downloaded from the publicly available Landsat satellite, a joint program of the US Geological Survey and NASA.[168]
4. Global climate regions from the Köppen Climate Classification System.[169]

**Caveats**

This approach has some limitations. First, although satellite-based measures of vegetation have been used extensively to measure greenness, NDVI does not provide information on the quality of greenness (e.g., curated park vs vacant lot), the type of green space (e.g., park vs. forest), the type of vegetation (e.g., shrubs vs. trees) or social characteristics (e.g., level of security). However, studies have demonstrated that NDVI performs adequately when compared with environmental psychologists’ evaluations of green spaces.[171] In addition, reviews of the literature on greenness and health have been undertaken and found consistent and strong evidence of associations of higher greenness measured by NDVI, with improvements in birthweights, physical activity, lower mortality rates, and lower levels of depression.[172] Second, missing values from GHS or from Landsat data due to cloud cover or other factors limit the generalizability of the findings.

**Future form of indicator**

Future versions of this indicator will continue to examine trends over time and will aim to estimate the proportion of each city that is green space, in addition to the overall average greenness of an urban centre and we are considering the addition of urban blue space. We will also explore options to integrate the greenness indicator with other indicators to investigate the associations between urban green space and multiple measures, including heat-related exposures and health effects, exposure of vulnerable populations, and loss of physical activity and/or labour capacity.

**Additional analysis**

**Table 34 Global percent moderate or above (population-weighted average peak-season NDVI ≥ 0.40)**

| Year | % > Moderate Greenness |
|---|---|
| 2015 | 28% |
| 2020 | 28% |
| 2021 | 27% |
| 2022 | 27% |

**Table 35 Global average population-weighted peak-season NDVI**

| Year | Pop-weighted average peak-season NDVI |
|---|---|
| 2015 | 0.34 |
| 2020 | 0.34 |
| 2021 | 0.34 |
| 2022 | 0.34 |

**Table 36 Population-weighted peak-season NDVI by HDI**

| HDI-level | | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|
| **Low** | | 0.31 | 0.30 | 0.29 | 0.29 |
| **Medium** | | 0.37 | 0.37 | 0.37 | 0.37 |
| **High** | | 0.31 | 0.32 | 0.31 | 0.32 |
| **Very High** | | 0.36 | 0.36 | 0.35 | 0.35 |

**Table 37 Population-weighted peak-season NDVI by climate region**

| Climate Region | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|
| **Arid** | 0.24 | 0.25 | 0.24 | 0.24 |
| **Continental** | 0.37 | 0.39 | 0.38 | 0.38 |
| **Polar** | 0.14 | 0.13 | 0.13 | 0.14 |
| **Temperate** | 0.35 | 0.35 | 0.35 | 0.35 |

| | | | | |
|---|---|---|---|---|
| **Tropical** | 0.39 | 0.38 | 0.38 | 0.38 |

**Table 38 Population-weighted peak-season NDVI by WHO region**

| **WHO Region** | **2015** | **2020** | **2021** | **2022** |
|---|---|---|---|---|
| **African** | 0.33 | 0.32 | 0.32 | 0.31 |
| **Americas** | 0.34 | 0.34 | 0.33 | 0.34 |
| **E Mediterranean** | 0.22 | 0.22 | 0.21 | 0.20 |
| **European** | 0.37 | 0.37 | 0.37 | 0.37 |
| **SE Asian** | 0.40 | 0.40 | 0.41 | 0.40 |
| **W Pacific** | 0.31 | 0.32 | 0.31 | 0.32 |

**Table 39 Percent moderate or above by HDI (population-weighted average peak-season NDVI ≥0.40)**

| **HDI-level** | **2015** | **2020** | **2021** | **2022** |
|---|---|---|---|---|
| **Low** | 18% | 18% | 15% | 13% |
| **Medium** | 37% | 36% | 40% | 36% |
| **High** | 17% | 17% | 16% | 18% |
| **Very High** | 37% | 38% | 33% | 36% |

**Table 40 Climate region percent moderate or above (population-weighted average peak-season NDVI ≥0.40)**

| **Climate Region** | **2015** | **2020** | **2021** | **2022** |
|---|---|---|---|---|
| **Arid** | 4% | 5% | 6% | 5% |
| **Continental** | 48% | 44% | 43% | 51% |
| **Polar** | 0% | 0% | 0% | 0% |
| **Temperate** | 28% | 27% | 26% | 24% |
| **Tropical** | 39% | 42% | 40% | 40% |

**Table 41 Percent moderate or above by WHO region (population-weighted average peak-season NDVI ≥0.40)**

| **WHO Region** | **2015** | **2020** | **2021** | **2022** |
|---|---|---|---|---|
| **African** | 21% | 20% | 18% | 18% |
| **Americas** | 28% | 28% | 25% | 25% |
| **E Mediterranean** | 5% | 6% | 5% | 4% |

| | | | | |
|---|---|---|---|---|
| **European** | 44% | 45% | 40% | 44% |
| **SE Asian** | 47% | 46% | 49% | 45% |
| **W Pacific** | 9% | 8% | 8% | 11% |

**Table 42 Percent moderate or above by Lancet Countdown region (population-weighted average peak-season NDVI ≥0.40)**

| LCD Region | 2015 | 2020 | 2021 | 2022 |
|---|---|---|---|---|
| **African** | 17% | 16% | 15% | 14% |
| **Asia** | 24% | 24% | 25% | 24% |
| **European** | 55% | 56% | 50% | 55% |
| **North American** | 60% | 58% | 49% | 51% |
| **Oceania** | 17% | 0% | 0% | 17% |
| **SIDS** | 27% | 41% | 45% | 50% |
| **South/Central America** | 12% | 11% | 13% | 11% |

**Table 43 Estimates of Urban Green Space by HDI (2015)**

| HDI-level | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **Low** | 0.32 | 0.26 | 0.31 | 0.25 |
| **Medium** | 0.38 | 0.31 | 0.37 | 0.31 |
| **High** | 0.34 | 0.27 | 0.31 | 0.25 |
| **Very High** | 0.37 | 0.29 | 0.36 | 0.28 |
| **Global Mean** | 0.35 | 0.29 | 0.34 | 0.27 |

**Table 44 Estimates of Urban Green Space by HDI (2020)**

| HDI-level | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **Low** | 0.31 | 0.26 | 0.30 | 0.25 |
| **Medium** | 0.38 | 0.32 | 0.37 | 0.31 |
| **High** | 0.35 | 0.28 | 0.32 | 0.25 |
| **Very High** | 0.36 | 0.29 | 0.36 | 0.28 |
| **Global Mean** | 0.35 | 0.29 | 0.34 | 0.27 |

**Table 45 Estimates of Urban Green Space by HDI (2021)**

| HDI-level | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **Low** | 0.31 | 0.25 | 0.30 | 0.24 |
| **Medium** | 0.38 | 0.31 | 0.37 | 0.30 |
| **High** | 0.34 | 0.27 | 0.31 | 0.25 |
| **Very High** | 0.36 | 0.28 | 0.35 | 0.27 |
| **Global Mean** | 0.36 | 0.28 | 0.35 | 0.27 |

**Table 46 Estimates of Urban Green Space by HDI (2022)**

| HDI-level | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **Low** | 0.30 | 0.25 | 0.29 | 0.24 |
| **Medium** | 0.37 | 0.31 | 0.37 | 0.30 |
| **High** | 0.34 | 0.28 | 0.32 | 0.26 |
| **Very High** | 0.36 | 0.28 | 0.35 | 0.27 |
| **Global Mean** | 0.35 | 0.28 | 0.34 | 0.27 |

**Table 47 Estimates of Urban Green Space by Climate Region (2015)**

| Climate Region | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **Arid** | 0.25 | 0.21 | 0.24 | 0.20 |
| **Continental** | 0.38 | 0.26 | 0.37 | 0.25 |
| **Polar** | 0.17 | 0.14 | 0.14 | 0.12 |
| **Temperate** | 0.37 | 0.30 | 0.35 | 0.28 |
| **Tropical** | 0.41 | 0.35 | 0.39 | 0.33 |

**Table 48 Estimates of Urban Green Space by Climate Region (2020)**

| Climate Region | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **Arid** | 0.26 | 0.21 | 0.25 | 0.20 |
| **Continental** | 0.40 | 0.27 | 0.39 | 0.26 |
| **Polar** | 0.15 | 0.13 | 0.13 | 0.11 |
| **Temperate** | 0.36 | 0.30 | 0.35 | 0.29 |
| **Tropical** | 0.40 | 0.35 | 0.39 | 0.33 |

**Table 49 Estimates of Urban Green Space by Climate Region (2021)**

| Climate Region | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **Arid** | 0.25 | 0.21 | 0.24 | 0.20 |
| **Continental** | 0.39 | 0.26 | 0.38 | 0.25 |
| **Polar** | 0.16 | 0.12 | 0.13 | 0.10 |
| **Temperate** | 0.36 | 0.29 | 0.35 | 0.28 |
| **Tropical** | 0.40 | 0.34 | 0.38 | 0.33 |

**Table 50 Estimates of Urban Green Space by Climate Region (2022)**

| Climate Region | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **Arid** | 0.25 | 0.21 | 0.24 | 0.20 |
| **Continental** | 0.39 | 0.27 | 0.38 | 0.26 |
| **Polar** | 0.17 | 0.13 | 0.14 | 0.11 |
| **Temperate** | 0.36 | 0.30 | 0.35 | 0.28 |
| **Tropical** | 0.40 | 0.34 | 0.38 | 0.33 |

**Table 51 Estimates of Urban Green Space by WHO region (2015)**

| WHO Region | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **African** | 0.35 | 0.28 | 0.33 | 0.26 |
| **Americas** | 0.36 | 0.31 | 0.34 | 0.29 |
| **E Mediterranean** | 0.23 | 0.20 | 0.22 | 0.19 |
| **European** | 0.38 | 0.29 | 0.37 | 0.28 |
| **SE Asian** | 0.41 | 0.34 | 0.41 | 0.34 |
| **W Pacific** | 0.33 | 0.25 | 0.30 | 0.23 |

Table 52 Estimates of Urban Green Space by WHO region (2020)

| WHO Region | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **African** | 0.34 | 0.27 | 0.32 | 0.26 |
| **Americas** | 0.36 | 0.30 | 0.34 | 0.29 |
| **E Mediterranean** | 0.23 | 0.20 | 0.22 | 0.19 |
| **European** | 0.38 | 0.29 | 0.37 | 0.28 |
| **SE Asian** | 0.41 | 0.35 | 0.40 | 0.34 |
| **W Pacific** | 0.34 | 0.26 | 0.32 | 0.24 |

**Table 53 Estimates of Urban Green Space by WHO region (2021)**

| WHO Region | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **African** | 0.33 | 0.27 | 0.32 | 0.25 |
| **Americas** | 0.36 | 0.30 | 0.33 | 0.28 |
| **E Mediterranean** | 0.22 | 0.19 | 0.21 | 0.18 |
| **European** | 0.38 | 0.28 | 0.37 | 0.27 |
| **SE Asian** | 0.41 | 0.34 | 0.41 | 0.33 |
| **W Pacific** | 0.33 | 0.26 | 0.31 | 0.24 |

**Table 54 Estimates of Urban Green Space by WHO region (2022)**

| WHO Region | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **African** | 0.33 | 0.27 | 0.31 | 0.25 |
| **Americas** | 0.36 | 0.30 | 0.34 | 0.28 |
| **E Mediterranean** | 0.22 | 0.19 | 0.20 | 0.17 |
| **European** | 0.38 | 0.28 | 0.37 | 0.28 |
| **SE Asian** | 0.41 | 0.34 | 0.40 | 0.33 |
| **W Pacific** | 0.34 | 0.26 | 0.32 | 0.25 |

**Table 55 Estimates of Urban Green Space by LCD region (2015)**

| LCD Region | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **Africa** | 0.33 | 0.27 | 0.31 | 0.25 |

| | | | | |
|---|---|---|---|---|
| **Asia** | 0.35 | 0.28 | 0.34 | 0.27 |
| **Europe** | 0.41 | 0.30 | 0.40 | 0.29 |
| **Northern America** | 0.40 | 0.32 | 0.39 | 0.32 |
| **Oceania** | 0.34 | 0.31 | 0.35 | 0.31 |
| **SIDS** | 0.38 | 0.34 | 0.38 | 0.33 |
| **South & Central America** | 0.34 | 0.30 | 0.31 | 0.27 |

**Table 56 Estimates of Urban Green Space by LCD region (2020)**

| LCD Region | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **Africa** | 0.32 | 0.26 | 0.30 | 0.24 |
| **Asia** | 0.35 | 0.29 | 0.34 | 0.28 |
| **Europe** | 0.41 | 0.31 | 0.40 | 0.29 |
| **Northern America** | 0.40 | 0.31 | 0.40 | 0.31 |
| **Oceania** | 0.33 | 0.30 | 0.33 | 0.30 |
| **SIDS** | 0.39 | 0.34 | 0.38 | 0.33 |
| **South & Central America** | 0.33 | 0.29 | 0.30 | 0.26 |

**Table 57 Estimates of Urban Green Space by LCD region (2021)**

| LCD Region | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **Africa** | 0.31 | 0.26 | 0.29 | 0.24 |
| **Asia** | 0.35 | 0.28 | 0.34 | 0.27 |
| **Europe** | 0.41 | 0.30 | 0.40 | 0.29 |
| **Northern America** | 0.38 | 0.31 | 0.38 | 0.30 |
| **Oceania** | 0.35 | 0.32 | 0.35 | 0.32 |
| **SIDS** | 0.38 | 0.35 | 0.38 | 0.34 |
| **South & Central America** | 0.33 | 0.29 | 0.30 | 0.26 |

**Table 58 Estimates of Urban Green Space by LCD region (2022)**

| LCD Region | Peak NDVI | Four-season NDVI | Pop. weighted Peak NDVI | Pop. weighted Four-season NDVI |
|---|---|---|---|---|
| **Africa** | 0.31 | 0.26 | 0.29 | 0.24 |

| | | | | |
|---|---|---|---|---|
| **Asia** | 0.35 | 0.28 | 0.34 | 0.27 |
| **Europe** | 0.40 | 0.30 | 0.39 | 0.29 |
| **Northern America** | 0.29 | 0.31 | 0.39 | 0.31 |
| **Oceania** | 0.34 | 0.31 | 0.34 | 0.31 |
| **SIDS** | 0.39 | 0.35 | 0.38 | 0.34 |
| **South & Central America** | 0.33 | 0.29 | 0.30 | 0.26 |

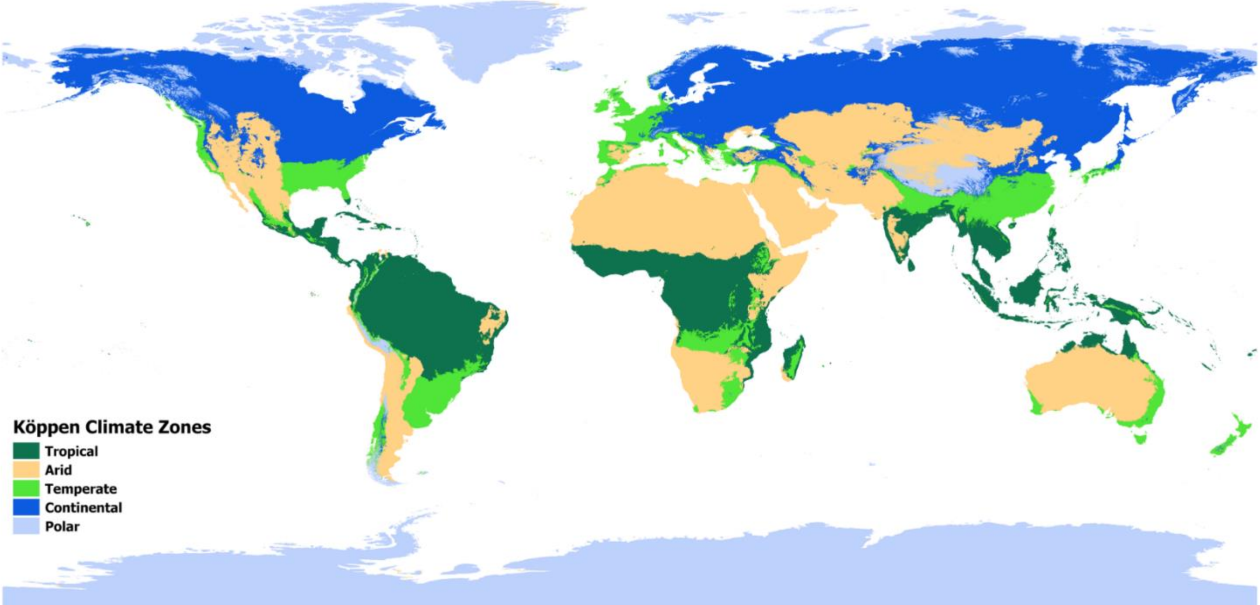


**Figure 76 Köppen Climate Regions. Designated climate regions of the world using the Köppen Climate Zones system**

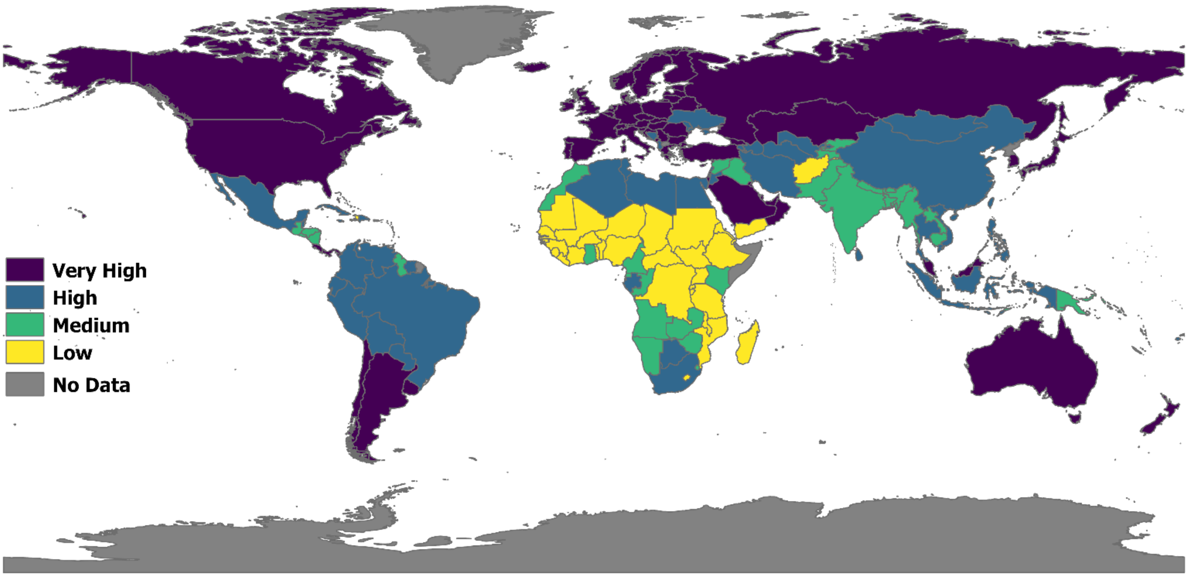


**Figure 77 Country Development Level. Development level as denoted by the Human Development Index or HDI.**

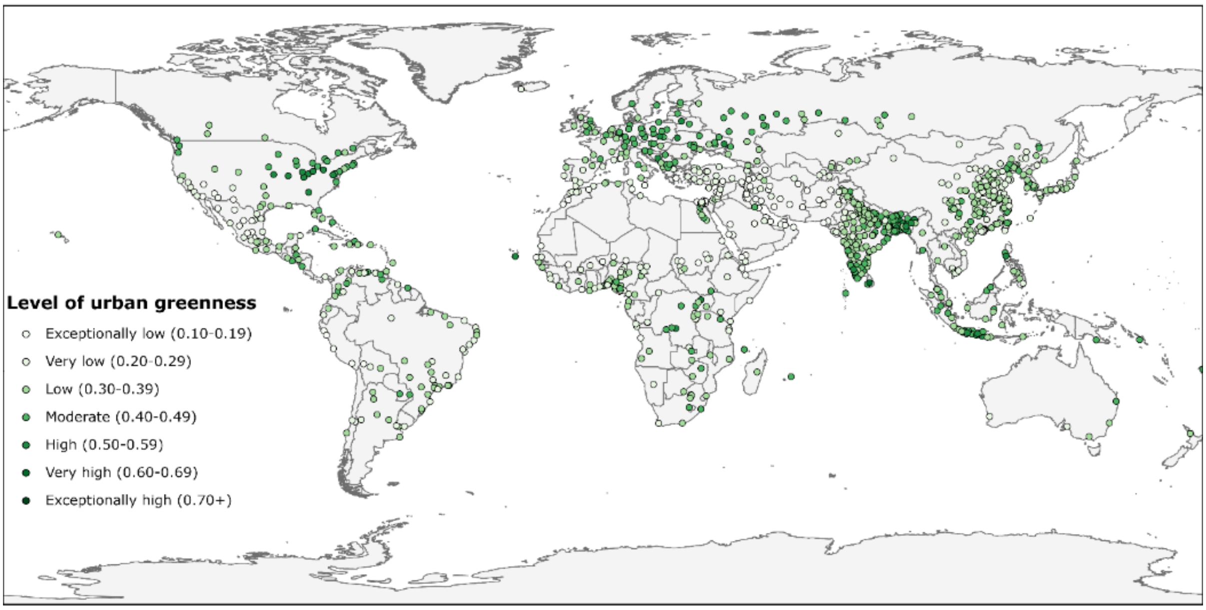


**Figure 78 Urban greenness in 1,041 urban centres in 2022.**

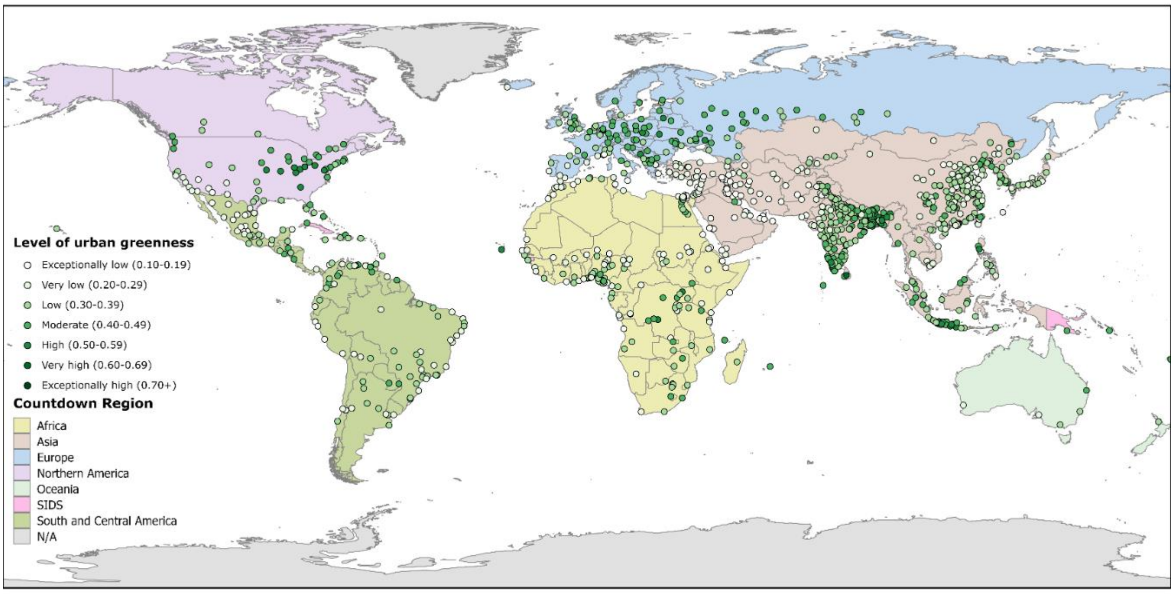


**Figure 79 Urban greenness in 1,041 urban centres in 2022. Levels of urban greenness were quantified on the basis of mean population-weighted peak-season normalized difference vegetation index (NDVI). The NDVI is a standard, satellite-based measurement used to estimate vegetation on a scale of -1.0 to 1.0**

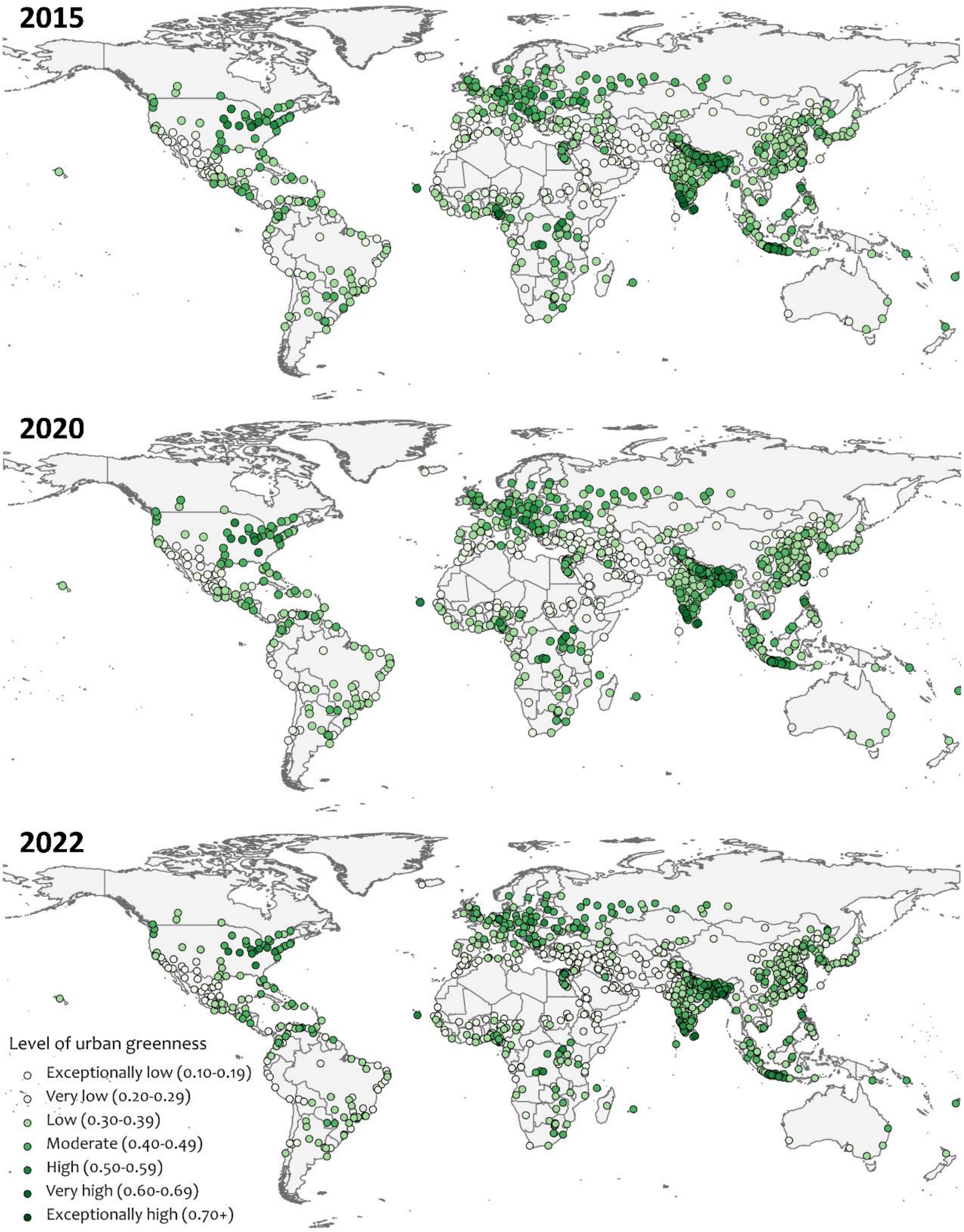


**Figure 80 Temporal changes in urban greenness. Levels of urban greenness change between 2015, 2020, 2021, 2022**

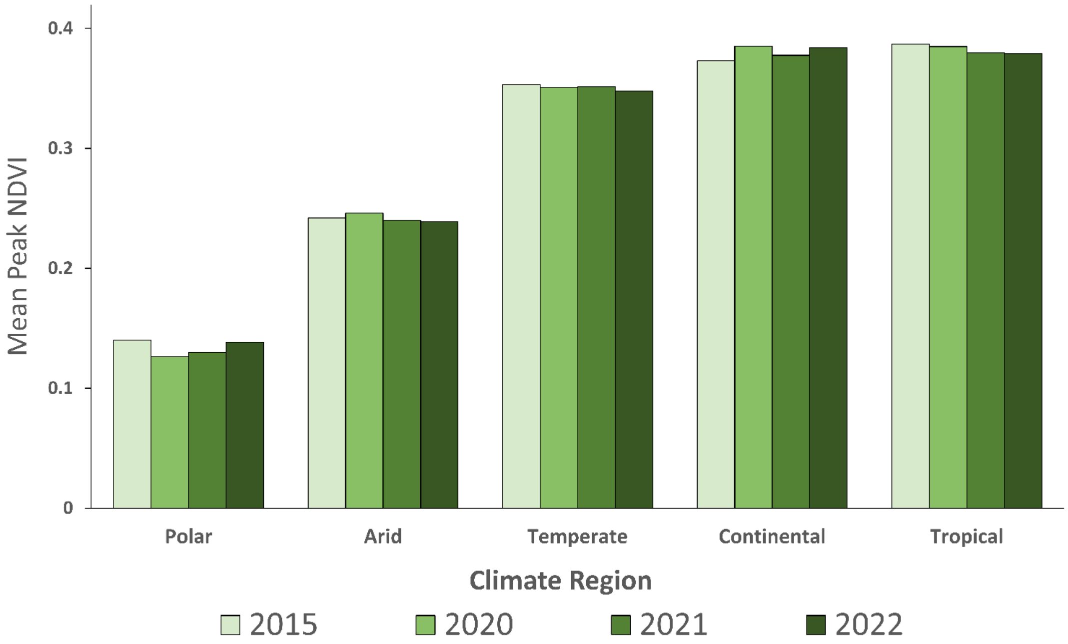


**Figure 81 Mean, population-weighted, peak-season NDVI by climate region and year**

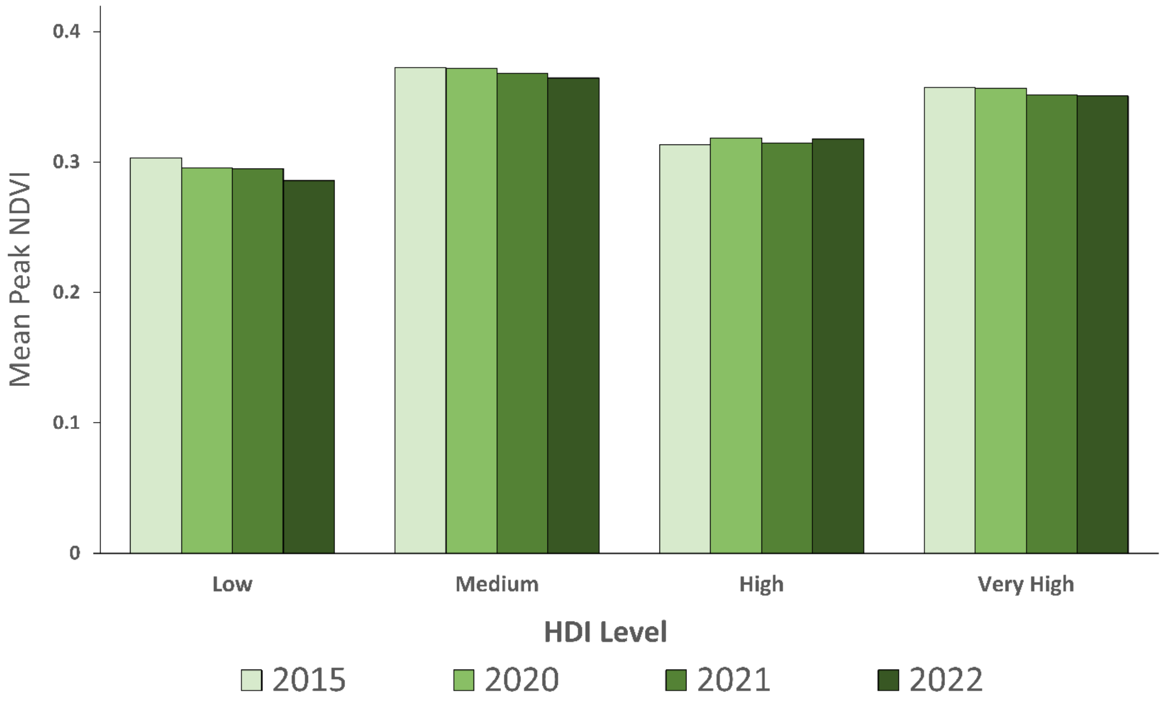


**Figure 82 Mean, population-weighted, peak-season NDVI by HDI and year**

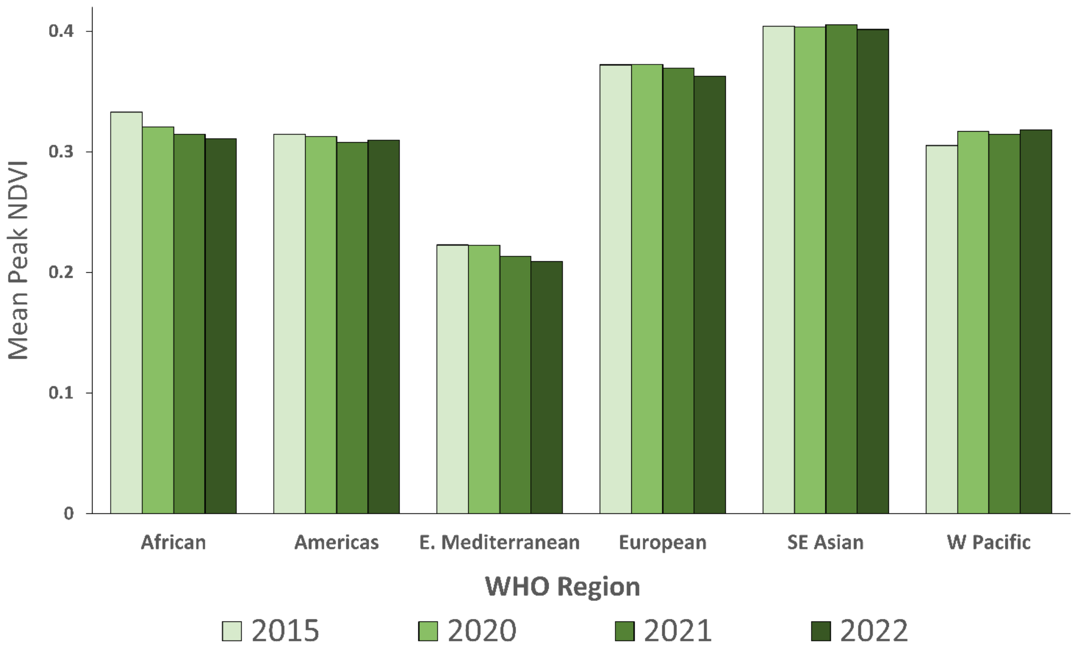


**Figure 83 Mean, population-weighted, peak-season NDVI by WHO region and year.**

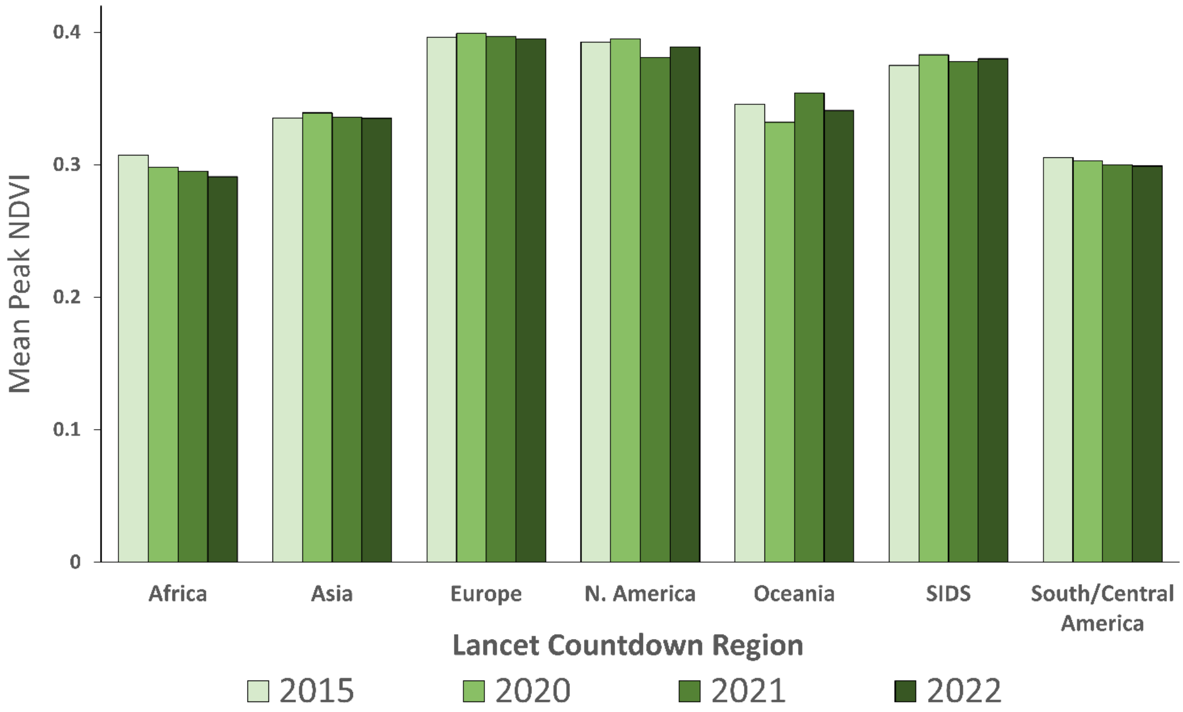


**Figure 84 Mean, population-weighted, peak-season NDVI by Lancet Countdown Region designation and year.**

### *Indicator 2.2.4: Global Multilateral Funding for Health Adaptation Programs*

**Indicator authors**

Carole Green

**Methods**

1. Data Collection:
    a. Data Collection on Funding Approved for Adaptation and Cross-Cutting Projects:

Data were collected from PDF files of Project Approval Documents, accessed via the GCF Project Portfolio, and collated into a spreadsheet.

The GCF Project Portfolio is accessible online from the GCF Website following the Prompts: https://www.greenclimate.fund/ > Projects & Programmes > Lists of Projects. The filter functionality was used to filter projects by 'Theme' [Adaptation] or [Cross-Cutting] and 'Date' [2022].

PDF files of the Project Approval Documents were downloaded from each of the relevant filtered projects, reviewed individually, and key data points were transferred into a spreadsheet, including:

- Project Reference Number
- Project Name
- Project Region
- Total GCF Financing
- GCF Financing Instrument (Concessional Loan, Grant, Equity, Guarantee)
- Percentage of Financing for Adaptation Elements of the Project, outlined in section A.4 Result Area(s)
- Percentage of Finance for 'Health, Food, and Water Security' Elements of the Project, outlined in section A.4 Result Area(s)
- Project objective described in Section B.3. Project/Programme Description of the Project Approval Document